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The purpose of this study was to investigate both the drag and noise reducing effects of riblet surface coatings on marine vehicles. The use of microgrooves, or riblets, for skin friction reduction originated at NASA Langley for aerodynamic applications. Water tunnel tests at the Naval Ocean Systems Center (NOSC), San Diego, have shown that reductions in skin friction of up to 8% can be achieved with sharp peaked riblets of appropriate size, when applied to a flat plate in a turbulent boundary layer. It is reasonable to suspect that a reduction in flow noise might accompany the measured reduction in skin friction. In fact, wind tunnel tests on a flat plate, conducted in cooperation with the University of California at Fullerton, indicate a 2-3 dB reduction in noise at the peak in the turbulent boundary layer spectrum when riblets are used. The flat plate laboratory experiments led to the current effort to study hydrodynamic drag and noise reduction on underwater vehicles. Because undersea vehicles are subject to fouling from marine organisms, the effect of biofouling on riblets was also studied.

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Drag and Noise Measurements on Underwater Vehicles
With a Riblet Surface Coating

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The purpose of this study was to investigate both the drag and noise reducing effects of riblet surface coatings on marine vehicles. The use of microgrooves, or riblets, for skin friction reduction originated at NASA Langley for aerodynamic applications. Water tunnel tests at the Naval Ocean Systems Center (NOSC), San Diego have shown that reductions in skin friction of up to 8% can be achieved with sharp peaked riblets of appropriate size, when applied to a flat plate in a turbulent boundary layer. It is reasonable to suspect that a reduction in flow noise might accompany the measured reduction in skin friction. In fact, wind tunnel tests on a flat plate, conducted in cooperation with the University of California at Fullerton, indicate a 2-3 dB reduction in noise at the peak in the turbulent boundary layer spectrum when riblets are used. The flat plate laboratory experiments led to the current effort to study hydrodynamic drag and noise reduction on underwater vehicles. Because undersea vehicles are subject to fouling from marine organisms, the effect of biofouling on riblets was also studied.

The research effort consisted of three experiments:

a. buoyant test vehicle experiment;
b. powered test vehicle experiment; and
c. riblet biofouling experiment.

A buoyant vehicle test was conducted in Lake Pend Oreille, Idaho, at the David Taylor Acoustic Research Facility. The test vehicle, belonging to the Admiralty Research Establishment, United Kingdom, is an axisymmetric body, 7.5 m long and 0.54 m in diameter. The test procedure required that the vehicle be hauled down to a depth of some 370 m. When the vehicle is released, it ascends under the force of buoyancy. Terminal velocity is attained in the first 40 m of ascent. An onboard recorder monitors vehicle depth and attitude so that the velocity and flight trajectory can be reconstructed following the test. Flush mounted piezoelectric pressure transducers on the vehicle were used to measure the boundary layer pressure fluctuations. A total of 17 buoyant ascents were carried out. Nine tests were conducted on the vehicle with riblets, and eight ascents were executed with no riblet coating. Riblets were applied to approximately 76% of the surface area. Because the wall shear velocity varies over the length of the axisymmetric body, the optimum riblet size varies as well. Fortunately, this variation is small and one riblet size was found to be adequate in attaining optimum skin friction reduction over most of the vehicle. A speed increase of approximately 2.3% +/- .3% was measured for the vehicle ascending with riblets. This compares well with the 2.3% speed increase predicted when an 8% reduction in friction drag is achieved on the riblet coated portion of the body. The pressure fluctuation measurements showed essentially no difference for runs with and without riblets. In other words, the vehicle achieved a speed increase without the attendant rise in noise level one would expect to measure on an uncoated body.

Sea tests were conducted on a propeller driven vehicle in waters off of San Diego. The axisymmetric body was 2.8 m in length and 0.32 m in diameter. Power was provided by an

external combustion engine burning a monopropellant fuel. As in the case of the buoyant vehicle tests, a series of baseline sea runs were followed by sea runs with riblets attached. The vehicle was programed to run a race track geometry at constant power. Velocity during the straight leg portion of the run geometry was measured using a pitot tube and recorded on-board. Based on two riblet sea runs and four runs without riblets, a speed increase of 1.6% +/- 1% was measured for the vehicle running with riblets. The large uncertainty in the results can for the most part be attributed to the variation in engine power from sea run to sea run.

The biofouling experiment was conducted with Dr. Elek Lindner of NOSC. Riblet samples of various sizes were submerged in San Diego Bay for a period of several months along with a smooth surface as a control. One of the samples was treated with an antifouling agent. This sample demonstrated excellent resistance to fouling. The untreated samples supported extensive marine growth, although there was no discernible difference between these samples and the control surface. Scanning Electron Microscope photos were used to document the final condition of all samples.

Although the current investigation does not address many important issues relevant to the subject of riblets applied to marine vehicles, the test results indicate that skin friction reductions measured on flat plates in the laboratory can be achieved on full scale ocean vehicles. Furthermore, this reduction in drag is accompanied by a measurable reduction in flow noise. With regard to the issue of biofouling, it is clear that the riblet geometry neither aids nor discourages the growth of marine organisms. Under favorable conditions, riblets will support extensive marine growth. It is equally clear, that antifouling agents applied to riblets are very successful in combating fouling organisms. The overall picture drawn from this study is encouraging for those involved in the design and operation of underwater vehicles and interested in increased range, greater speed, reduced fuel consumption or reduction in self-noise.

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